Figure 95a

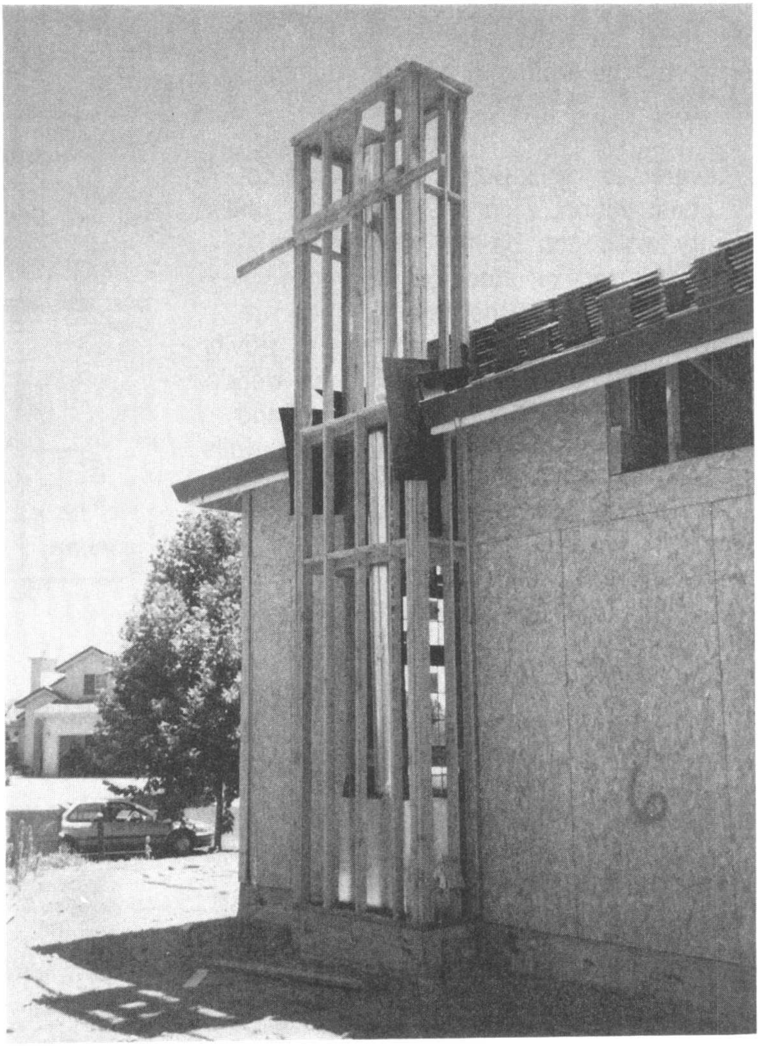


Figure 95b

## 11. CONCRETE MASONRY

Walls of hollow concrete masonry are frequently used to resist earthquake forces in residential construction. In most respects the same principles apply as with wood and steel stud framed buildings. The masonry walls will act as shear walls. A complete earthquake resisting system includes roof and floor diaphragms, chords, collectors, shear walls and foundations. Because masonry walls are heavier than stud framing, it follows that inertial forces will be greater and the earthquake loads that must be resisted by the system will be larger. Because the forces to be resisted are larger, a greater demand is placed on the components of the resisting system. Therefore, care should be exercised in limiting openings in roof diaphragms and rigidly adhering to prescribed diaphragm ratios and diaphragm nailing requirements. Earthquake loads perpendicular to walls are more significant than for light frame construction. Therefore, the walls must be well anchored to the diaphragm at the top of the wall and to the foundation. See Figures 96 and 97.

Masonry dwellings covered by this Guide are limited to one and two story construction. Figure 98 shows a one story building. Masonry walls can be full height from ground floor to roof; or wood or steel framing may continue above the masonry from the floor line to the roof for two story construction. Except for veneer, gravity loads from masonry should never be supported by wood framing. It is desirable to keep floor plans regular and rectangular. It is also good practice to locate shear walls so as to keep the ratio of length to width of horizontal diaphragms (diaphragm ratio) below those shown in Table 3, page 39.

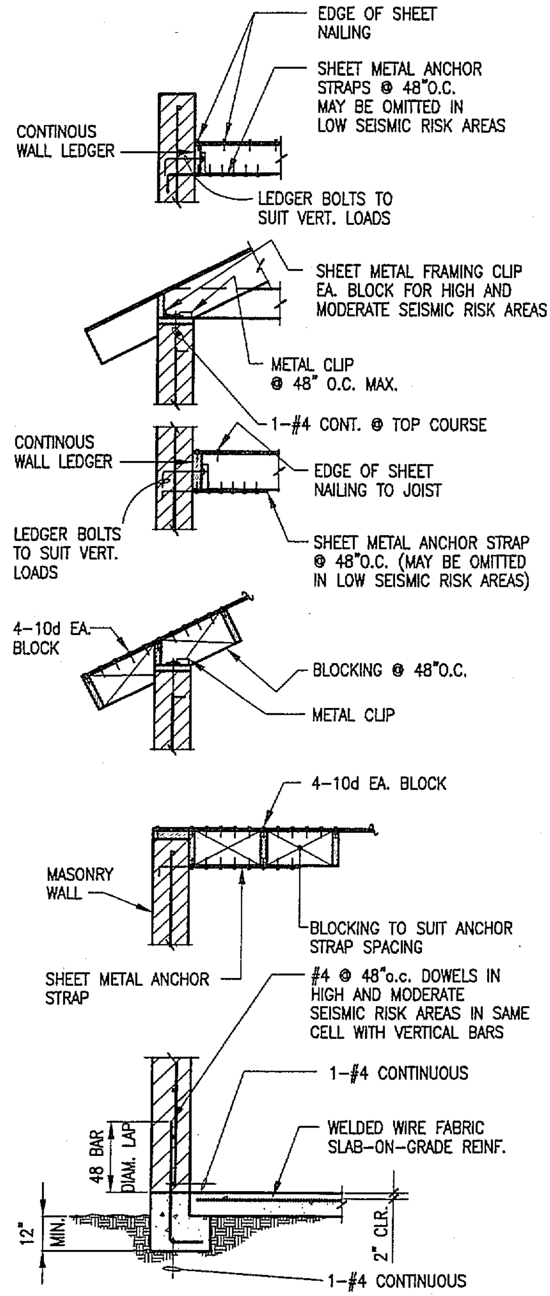



Figure 97

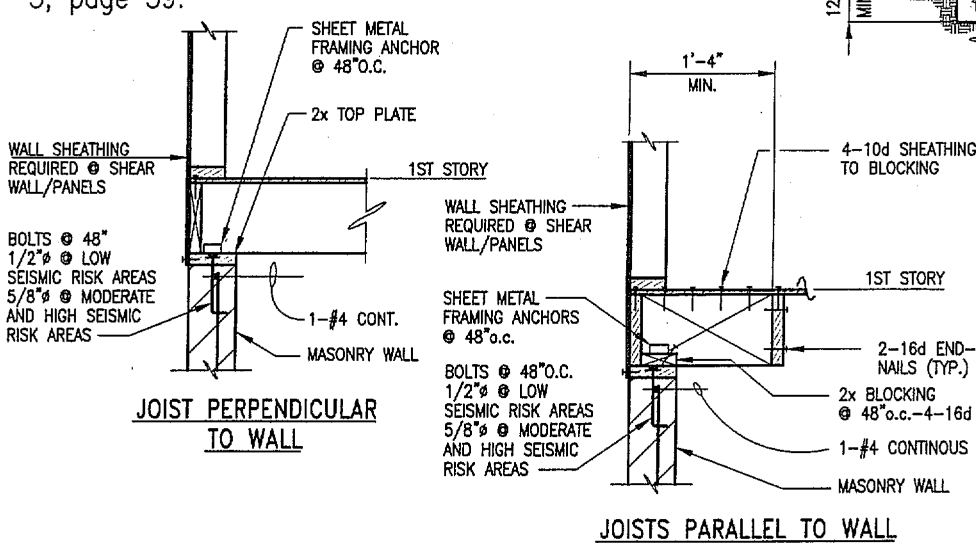



Figure 96

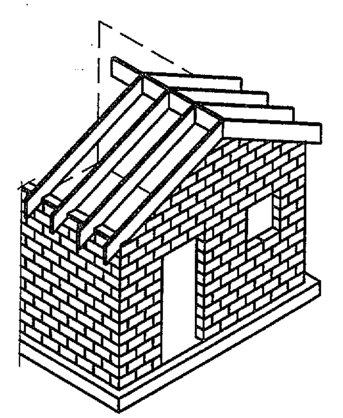


Figure 98

A 4'–0" width of shear wall should be maintained in each of the exterior elevations of the building. For unreinforced shear walls, where permitted, the minimum width should be 6'–0". To reduce the possible detrimental effects of rotation of the diaphragm, shear walls should be located near corners of the building in mutually perpendicular directions. Maximum distance between shear panels is 35 feet. See Figure 99. If the walls intersect at the corners, at least one vertical reinforcing bar should be placed at the corner and horizontal reinforcing bars, where needed, should extend into the corner and be lap spliced around the corner, See Figure 105.

Foundations for concrete masonry walls should be continuous wall footings or slabs–on–grade with thickened edges. See Figure 100. Footings should be continuous around the exterior of the building and under interior shear walls. Footings should be reinforced in high seismic risk areas, and reinforced masonry walls should be doweled to the footings. See Figure 101. Unless required by the building code or local regulations, footings need not be reinforced in low seismic risk areas.

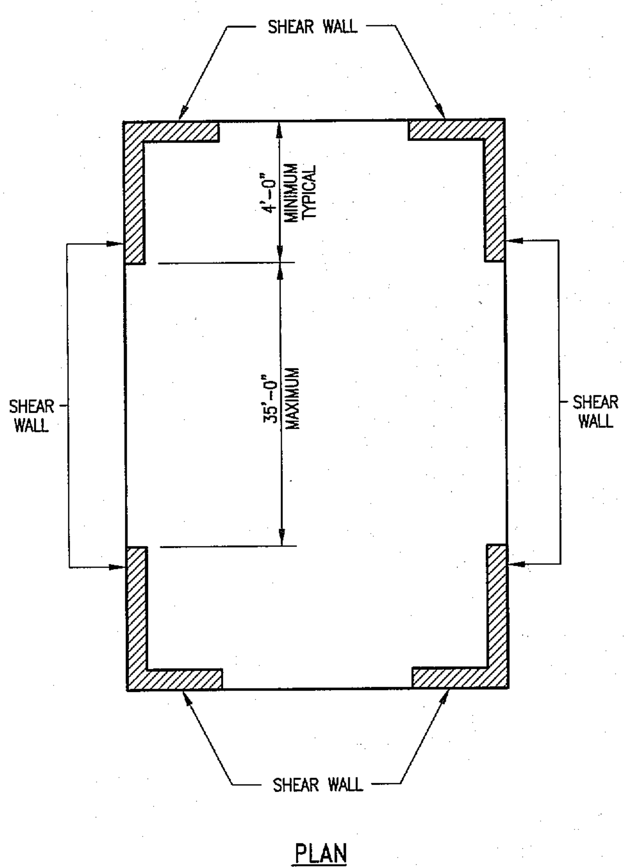



Figure 99

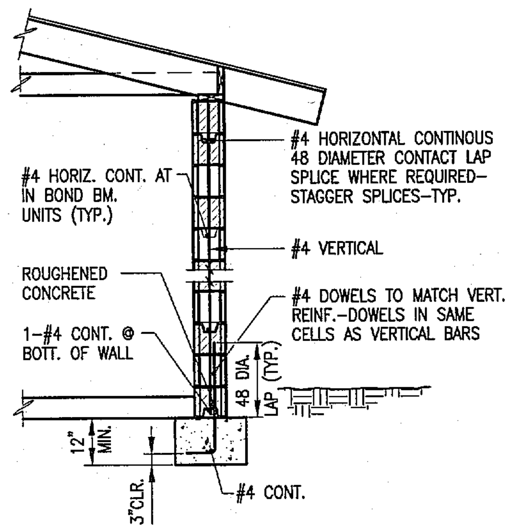



Figure 100

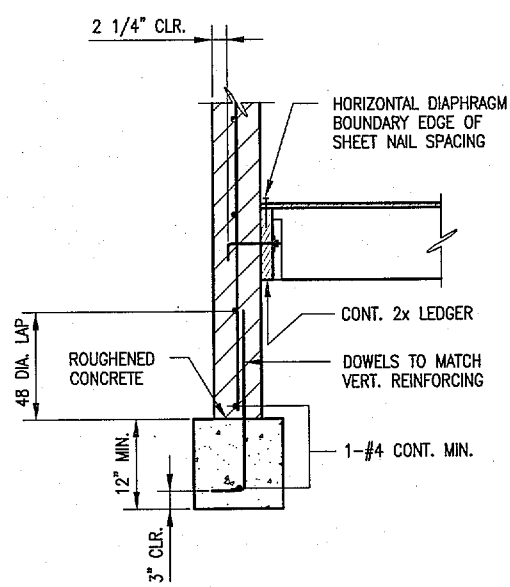
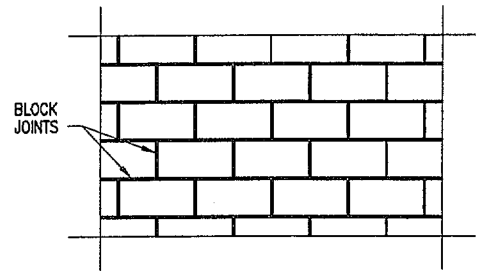



Figure 101

Builders have a choice of bond patterns for masonry walls. The pattern most often used is common or running bond. See Figure 102a. In common bond, units in adjacent courses overlap. Where the overlap is at least 25% of the length of the units, the wall is considered to be running bond.

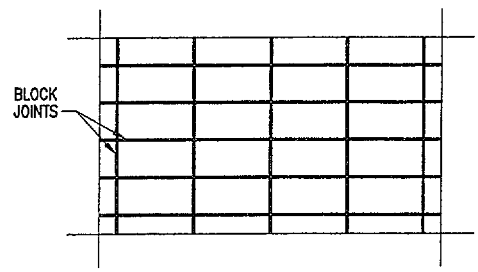



RUNNING BOND

Figure 102a

Running bond is the most effective pattern for resistance to earthquakes and is especially desirable for high seismic risk areas. For this pattern, the vertical joints are offset in each course thus bonding the masonry units together for the full height of the wall and increasing its strength.

Where there is no overlap of units, the pattern is referred to as stack bond. See Figure 102b. In stack bond masonry, the vertical joints line up for the full height of the wall which results in a weak vertical plane within the wall. For high and moderate seismic risk areas, reinforcing of stack bond masonry is desirable and open end units with walls grouted solid are recommended in order to compensate for the inherent weakness of the stack bond pattern. Even in low seismic risk areas a minimum amount of horizontal reinforcing across the vertical joints is desirable. Horizontal reinforcing may be supplied by joint reinforcing @ 16" o.c. placed in the mortar bed joints.




STACK BOND

Figure 102b

In high seismic risk areas, masonry walls require vertical and horizontal reinforcing. See Figure 103. Vertical bars must extend to the the top of the masonry wall including the parapet, if there is one. Where single length vertical bars cannot be used, lap splices of at least 48 bar diameters are required. Vertical bars should be in the same cell as the footing dowels and should be wire-tied to horizontal bars at the top and bottom of the wall and at intermediate locations. However, where foundation dowels are misplaced, vertical bars may be offset up to a maximum of 8". Vertical reinforcing should be located at every wall intersection and door and/or window jamb. Metal positioners can be used to hold the vertical bars in place. In moderate seismic risk areas, vertical bars need only be placed at corners of intersecting walls, at each end of shear walls and at door and window jambs. The vertical reinforcing bars should be doweled to footings.

In high and moderate seismic risk areas, horizontal reinforcing bars should be placed at the diaphragm levels around the perimeter of the floor and roof diaphragms to resist chord tension forces. The chord bars should be as long as possible to minimize splices and be spliced at corners.

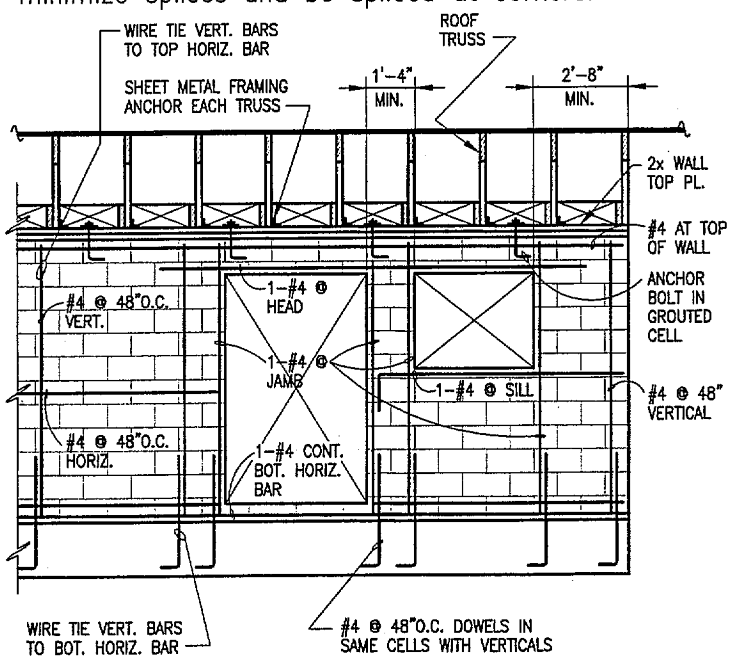



Figure 103

Except for chord bars, horizontal bars can be replaced by ladder wire reinforcing placed in horizontal mortar joints usually at 16" o.c.. Required horizontal reinforcing bars should be placed in bond beam units and not in the mortar joints. See Figures 104 and 105. Reinforcing requirements should be verified with governing building codes and/or local practices.

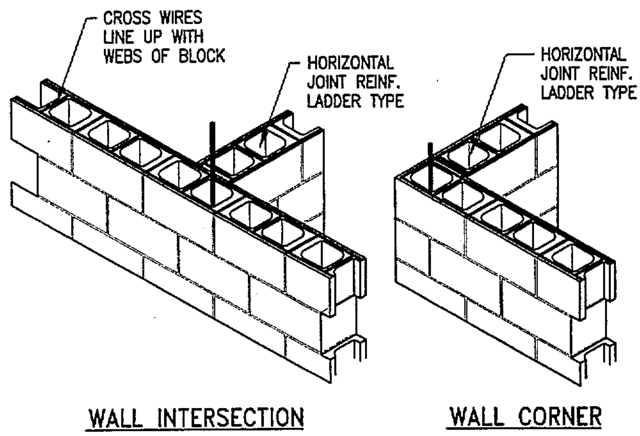



Figure 104

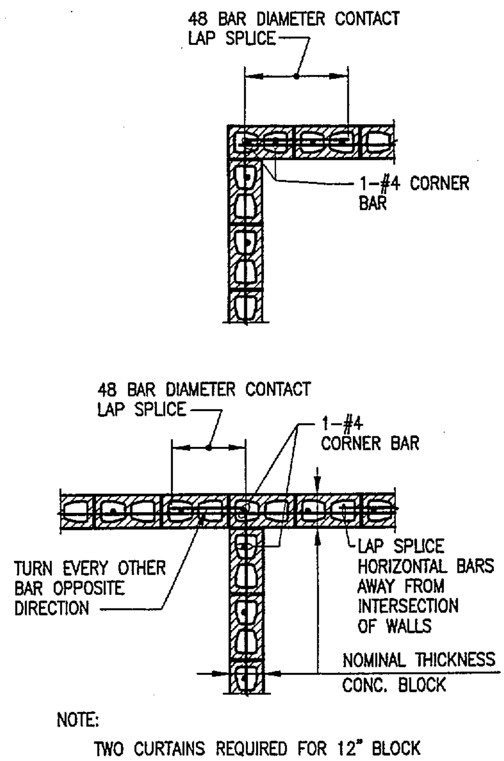



Figure 105

Every cell with vertical reinforcing must be fully grouted. See Figure 106. Horizontal bars in bond beams must also be grouted. In high seismic risk areas, consideration should be given to grouting all the cells.

As described before, and now described in more detail, where masonry walls act as shear walls, it is necessary that the floor and roof diaphragms be connected to the walls. Where the joists or rafters rest on top of the wall, the diaphragm sheathing must be nailed to blocking or joists that are nailed to the wall top plates. The top plates must be secured to the top of the wall with bolts that are grouted into the cells of a bond beam. See Figures 107 and 108 for conditions at roof framing.

If diaphragm sheathing abuts the face of a wall it must be nailed to a ledger. Ledgers must be bolted to the face of a wall with bolts placed in grouted cells. See Figures 109 and 110. In high and moderate seismic risk areas, wall ledger bolts should be a minimum of 5/8" diameter and should be headed or have hooks at the embedded non-threaded end. Spacing should not exceed 48" on center. For low seismic risk areas, ledger bolts used to resist vertical loads will generally be adequate to resist earthquake loads as well. In any case, ledger bolts must be spaced as required to support dead and live loads.

Ledgers and top plates should have a bolt not less than 9" from the ends of each piece including butt splices. Plates and ledgers should be installed with pieces as long as possible to minimize splices.

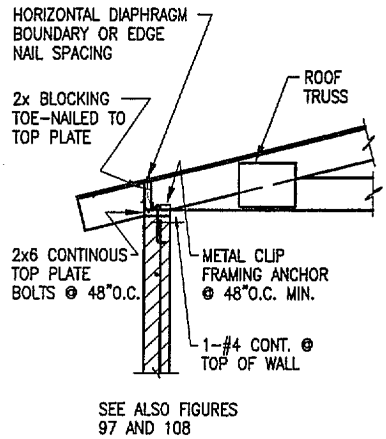



Figure 107

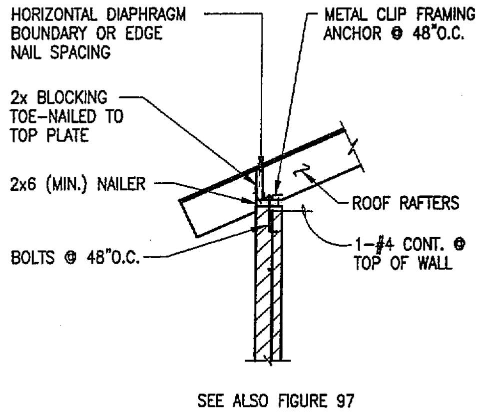



Figure 108

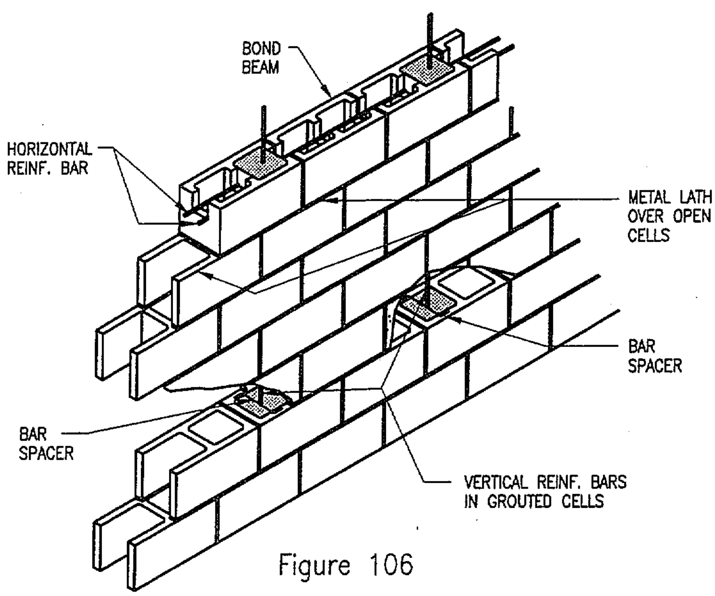
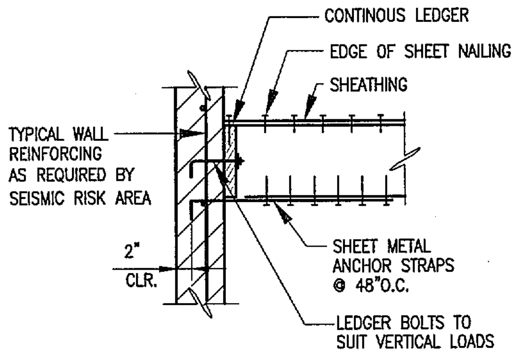



Figure 106

In high seismic risk areas where diaphragm sheathing nailed to wall ledgers is the only sheathing–to–wall connection, it has proven to be inadequate for providing lateral support for the walls. Nails may pull through the sheathing and/or ledgers may fail in bending across the grain of the wood (crossgrain bending), and allow the wall to fall away.

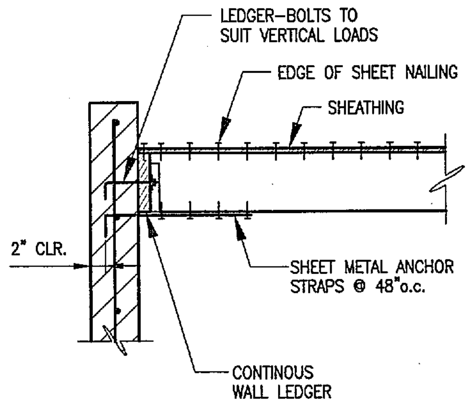
In high and moderate seismic risk areas, prefabricated anchor straps should be used to anchor walls to horizontal diaphragms so as to transfer seismic forces without allowing crossgrain bending in ledgers. Anchors should be spaced a maximum of 4'–0" on center completely around the exterior of the building. Interior masonry walls should also be anchored to floor and roof framing in the same manner. The anchor straps must be embedded in grouted cells and be attached to joists or blocking. See Figures 109 and 110. They should be carefully located and in line with and parallel to joists, rafters or blocking. The straps should be attached by nails to the top or bottom edges of framing members or by bolts or nails to the face of framing members. Where floor and roof framing run parallel with the face of the walls, anchor straps may be nailed to the underside of solid blocking cut in between joists or rafters. See Figure 111. Straps should be long enough to extend from the face of the wall a minimum of two joist or rafter spaces. Twisted or riveted strap anchors should be avoided. Floor and roof sheathing should receive extra nailing to the members holding anchor strap.

Local regulations should be consulted for bracing of masonry walls for wind loads during construction.




JOIST PARALLEL TO WALL

Figure 109




JOIST PERPENDICULAR TO WALL

Figure 110

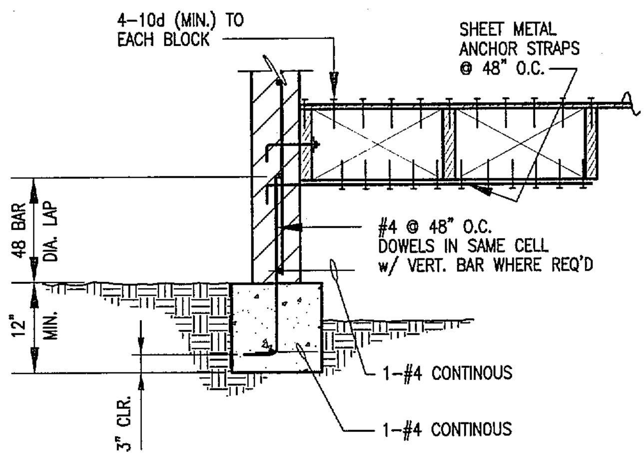



Figure 111

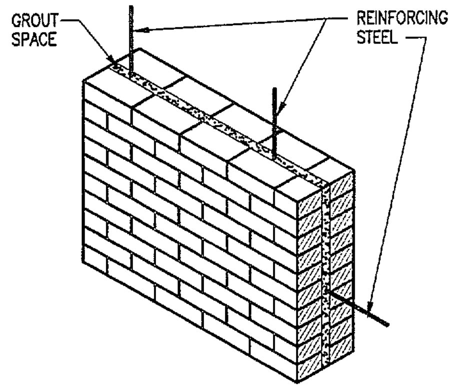
## 12. CLAY MASONRY

As with concrete masonry construction, walls built with clay brick masonry units may be used in residential construction to act as shear walls to resist earthquakes. Location, spacing, width, height to width ratios for shear walls and foundation requirements are the same as for concrete masonry. Anchorage of walls for loads perpendicular to the face of walls and wall ledger details are also the same. Detailing and reinforcing requirements for hollow units are the same as for hollow concrete masonry units. Refer to Section 11 CONCRETE MASONRY.

Brick shear walls built with solid units must have reinforcing in high risk areas. Reinforced walls are generally constructed with two wythes of brick separated by a grout space. See Figures 112 and 114. The vertical and horizontal reinforcing is positioned within the grout space and fully embedded in grout although, as with hollow masonry, the grout space need not be solidly filled. Additional vertical wall reinforcing should be placed at the jambs of door and window openings and a horizontal bar should be located at door and window heads. The two wythes of brick should be held together with metal wall ties or ladder wire joint reinforcing placed in the mortar joints. Ties should be provided for each four square feet of wall surface. The maximum vertical spacing of wall ties or wire joint reinforcing should not be more than 24"

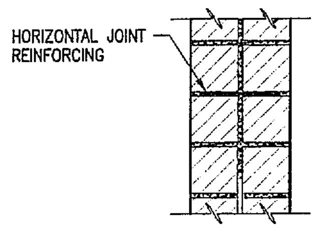
Empirical design rules for solid masonry construction can be found in ACI 530/ASCE 5/TMS402 Building Code Requirements for Masonry Structures and in model codes. According to these rules, shear walls must have a minimum thickness of 8". Shear walls must conform to a height to thickness ratio of 18 or less. Reinforcing is as required by empirical design rules. Empirical design rules are not generally applicable in high seismic risk areas.

Brick shear walls in moderate and low seismic risk areas can be two wythe cavity wall construction and need not be reinforced unless required by the governing code. See Figures 113 and 114. The brick courses should be laid up in running bond with metal ties placed between the wythes as for grouted walls.



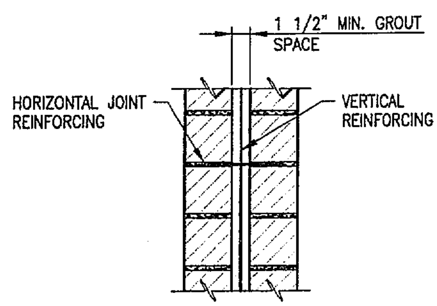

TWO WYTHE
GROUTED REINFORCED

Figure 112




TWO WYTHE
NOT REINFORCED

Figure 113




TWO WYTHE
GROUTED REINFORCED

Figure 114

## 13. MASONRY AND STONE VENEER

Masonry and stone is often used as veneer attached to wood stud or steel stud backing. Satisfactory performance of veneer can be achieved if the support system provides an adequate foundation, strong and stiff backing, proper attachment of the veneer to the backing and good workmanship. Mortar is an important ingredient of veneer and all mortar joints should be completely filled. Mortar joints should be tooled to increase the water tightness of the wall. A portland cement–lime mortar is recommended.

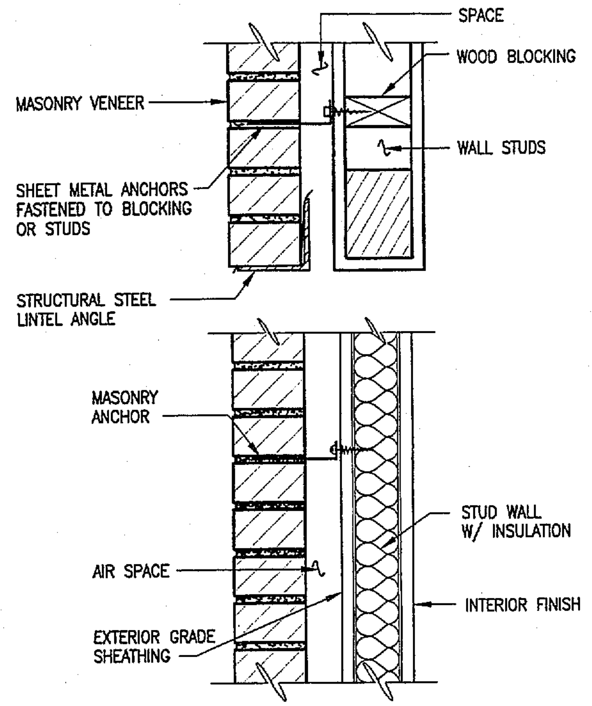
Masonry or stone veneer should be supported on a concrete foundation such as the wall footing, an independent foundation or noncombustible supports such as steel lintel angles. See Figure 115.

For the best performance in earthquakes, it is recommended that a Structural Wood Panel backing be used on the veneer side of the supporting walls and gypsum board sheathing be used on the room side. See Figures 115 and 116. Structural Wood Panels should be exterior grade and not less than 3/8" in thickness. For low seismic risk areas exterior grade gypsum board sheathing 1/2" thick may be used for sheathing on the veneer side of the walls. Non–corroding nails or screws should be used to fasten the veneer anchors to the sheathing and studs. Steel studs should be 18 gage minimum with G90 zinc galvanized coating.

Veneer should have a 1" space between the veneer and the wall sheathing. See Figure 115. This space may be filled with grout for better performance. Building paper should be attached directly to the face of the sheathing for wood studs or self–furring insulation board can be attached directly to the face of steel studs.

Veneer must be anchored with sheet metal or wire ties fastened with screws penetrating through the building paper and sheathing and into the studs. Ties should project into mortar joints. In high seismic risk areas, veneer should have joint reinforcing engaging the ties in the mortar joints of the veneer. Ties should be galvanized.

A small diameter wire placed in the horizontal mortar joint is recommended for moderate and high seismic risk areas. The wire should be placed in the same mortar joint with the veneer anchors. This detail is recommended for stack bond in all seismic risk areas.




BRICK VENEER WALL

Figure 115

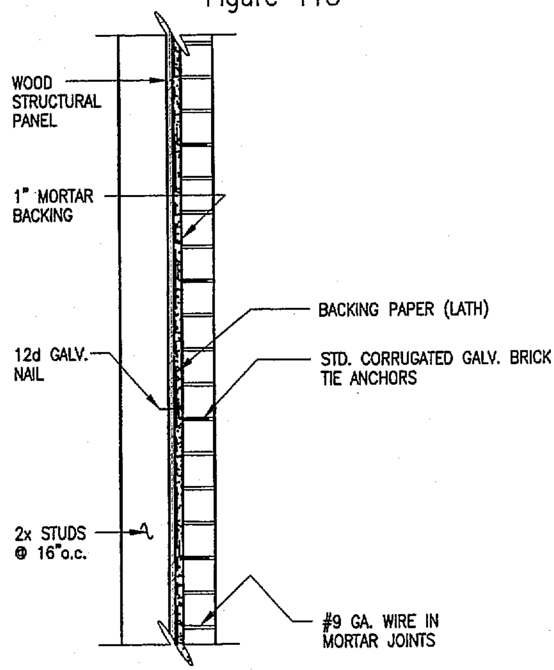



Figure 116

## 14. BUILDING CODES AND REFERENCES

Building code provisions are developed, adopted and enforced by jurisdictions to safeguard the health, safety, and welfare of building occupants. Building code requirements that relate to earthquakes are intended to prevent collapse and local failures that might endanger the safety of occupants and, to a lesser extent, mitigate economic loss due to property damage.

Building codes specify procedures that should be followed in the construction of buildings and their critical structural components. Specific attention is given to shear walls or other types of bracing, connections of floors and roofs to walls, connections of walls to foundations, and anchoring of major appliances such as water heaters. Codes require that all structural components that resist seismic forces be connected with adequate strength and stiffness to provide a continuous load path to the foundation.

Seismic requirements in codes are developed from information provided by research and lessons learned from past earthquakes. Risk and severity of earthquakes vary throughout the United States. The country is divided into seismic risk areas based on estimated frequency and magnitude of earthquake activity. Because of the expected severity of earthquakes in high seismic risk areas, provisions for earthquake resistance in these areas are more stringent than are required elsewhere.

As described in the INTRODUCTION, there are three model codes being used in the United States regulating the design and construction of buildings. They are the Uniform Building Code (UBC), the BOCA National Building Code (NBC) and the Standard Building Code (SBC). They are published by different organizations and are used in areas of the country as follows:

- The BOCA National Building Code (NBC) – northeastern states
- The Standard Building Code (SBCCI) – southern states.
- The Uniform Building Code (UBC) – states west of the Mississippi.

In addition to the three codes noted above, the Federal Emergency Management Agency (FEMA) has published the "NEHRP (National Earthquake Hazard Reduction Program) Recommended Provisions for the Seismic Regulations of New Buildings" which also contains provisions for residential seismic resistant construction. The NEHRP document serves as the basis for the seismic provisions of the NBC and SBC codes and will be used as a basis for the seismic aspects of the IBC (International Building Code).

To consolidate and standardize the requirements for detached one–and two–family dwellings, the CABO One and Two Family Dwelling Code was created by the three model code agencies. However, not all State and local governments have adopted the CABO One–and Two–Family Dwelling Code. In the following discussion of codes, emphasis will be placed on the seismic requirements of the CABO One and Two Family Dwelling Code. In high seismic risk areas, local jurisdictions using the UBC may not recognize the CABO One and Two Family Dwelling Code and require the UBC provisions to be observed.